Space Solar Power Developments at Boeing

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SCTM Technical Interchange Meeting

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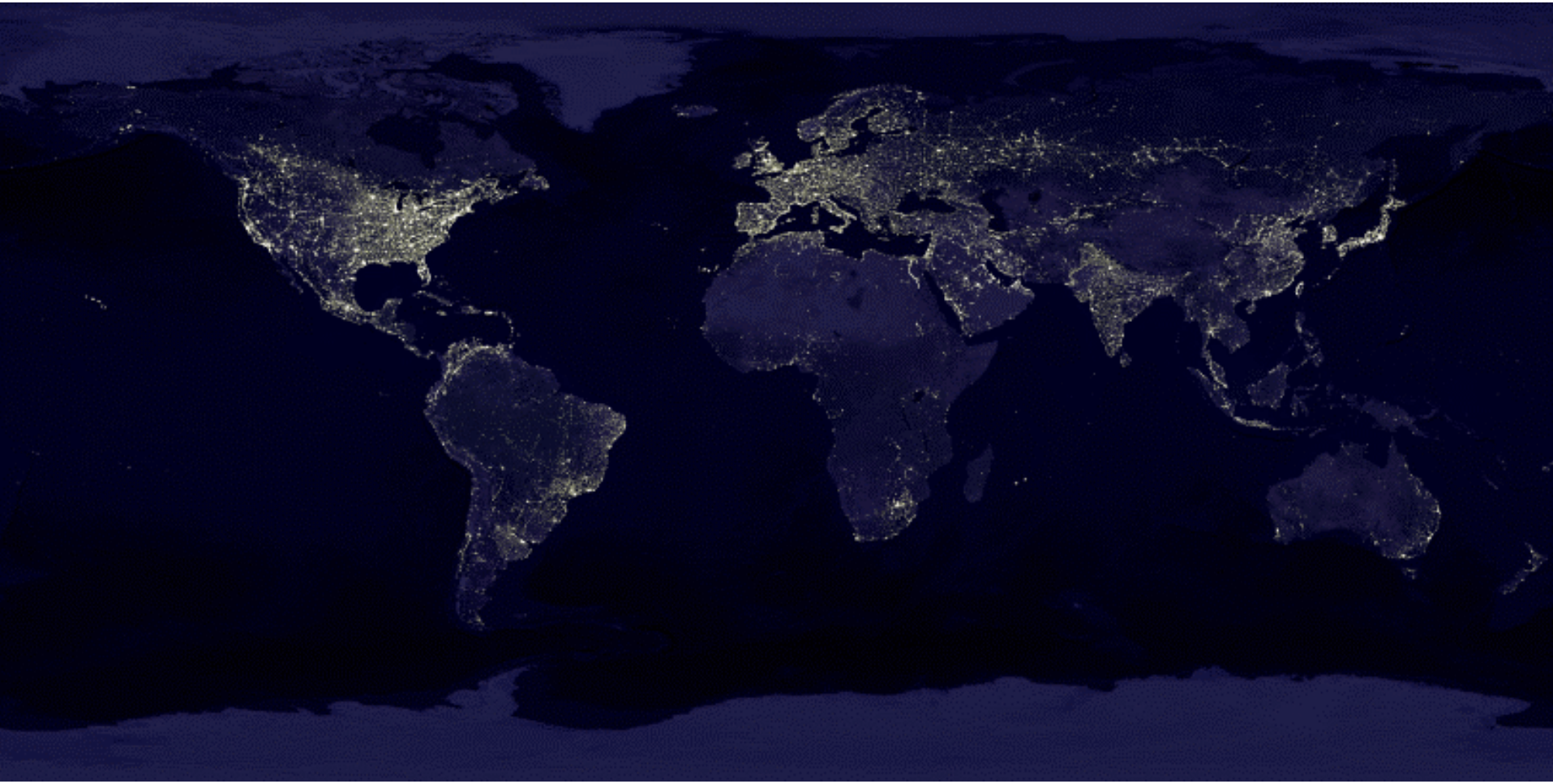
SSP Developments at Boeing

- Recap of Key Findings from Prior Research
  - Far Term Space Systems to beam power to Earth
  - Model System Concept 1: 100 kWe satellite
  - Model System Concept 2: 10 kWe lunar system
- Recent Activities
  - Harvey Mudd College: Laser Transmitter
  - University of Colorado: Boulder: Laser Receiver
- Next Steps
  - Carnegie Mellon University: Photovoltaic Rover

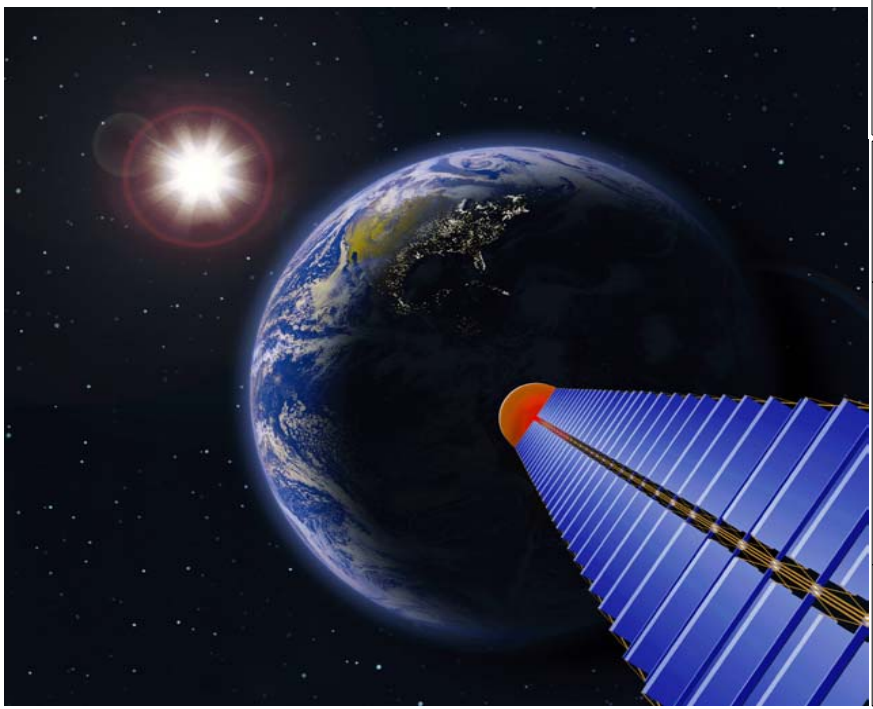
Global Power Consumption

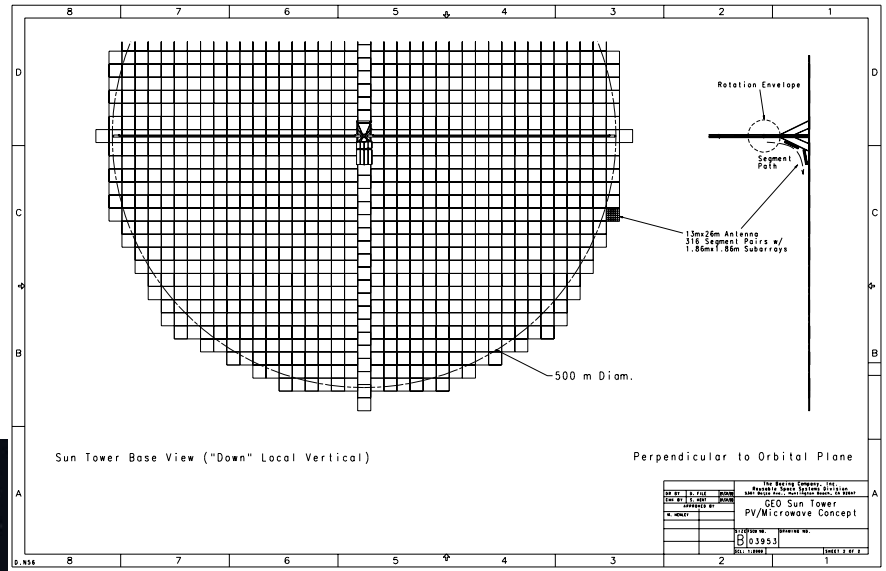


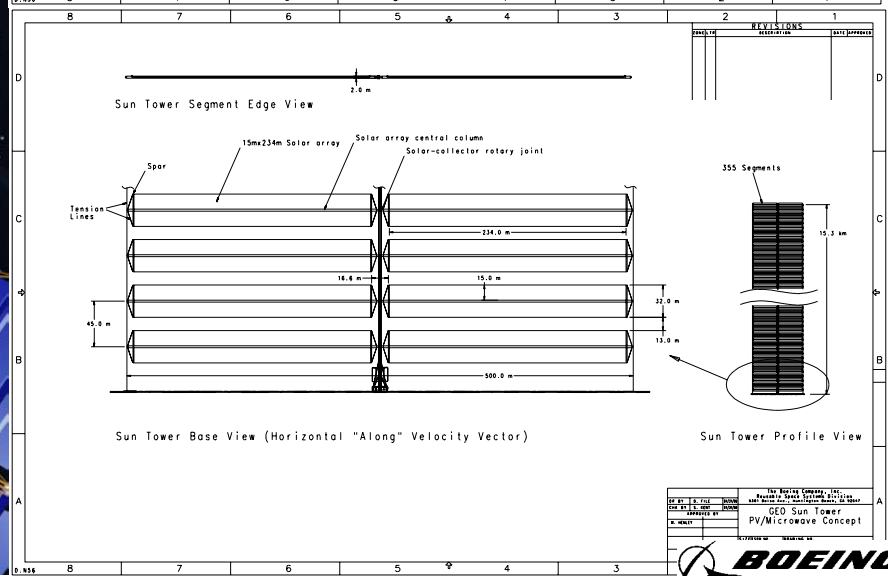
Remote Sensing of Current Global Power Consumption:
A Composite Satellite Photograph of the Earth at Night

Initial Photovoltaic / Microwave SPS GEO Sun Tower Conceptual Design

- Design followed Fresh Look Study
- 500 meter diameter transmitter
- 15.3 km length (gravity gradient)
- 355 identical satellite segments
- Autonomous assembly in GEO
- Large rectenna receivers on Earth







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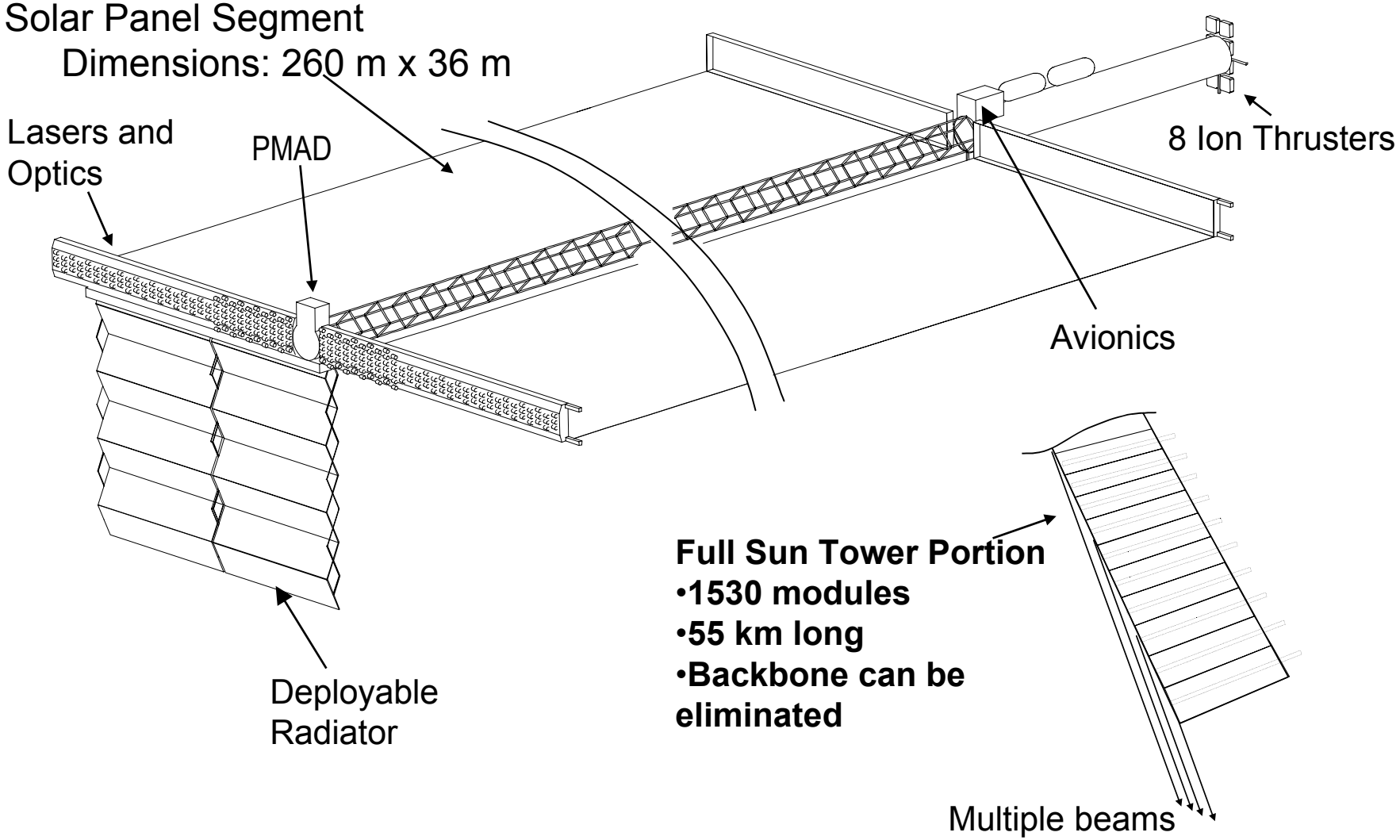
Photovoltaic / Laser-Photovoltaic SPS GEO Sun Tower-Like Concept



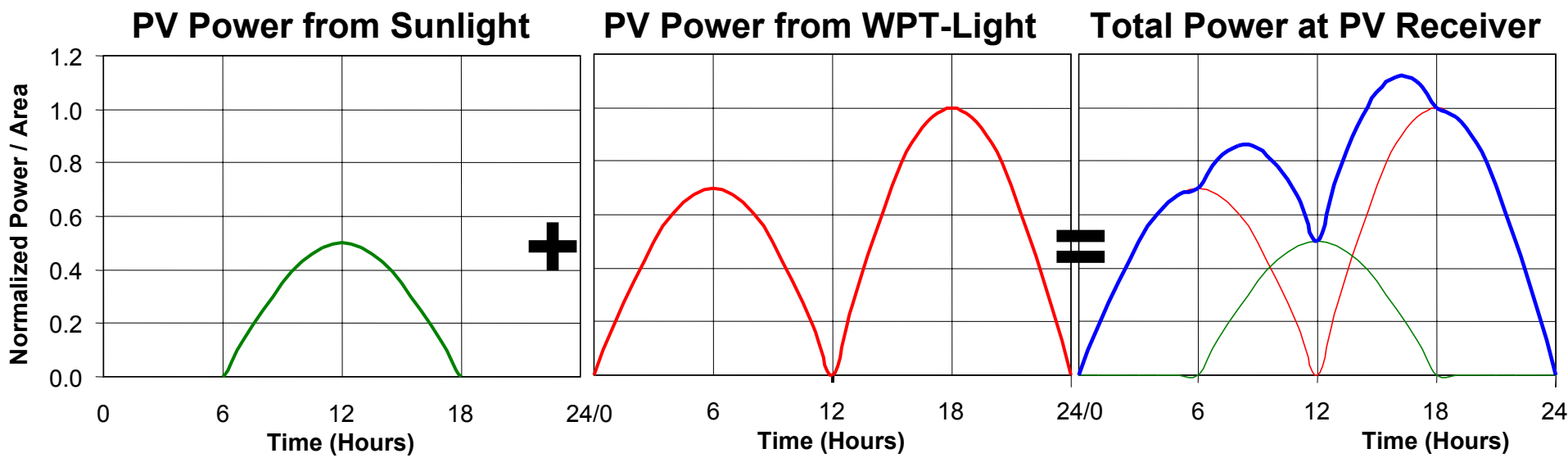
Synergy Sunight and Laser-PV WPT for Terrestrial Photo-Voltaic Power Production

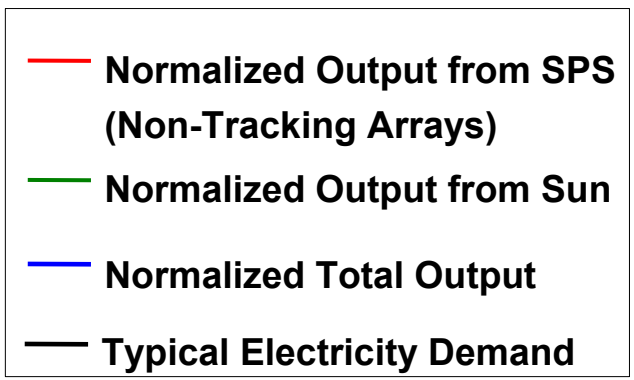
- Large photo-voltaic (PV) power plants in Earth's major deserts (Mojave, Sahara, Gobi, etc.) receive & convert light from 2 sources:

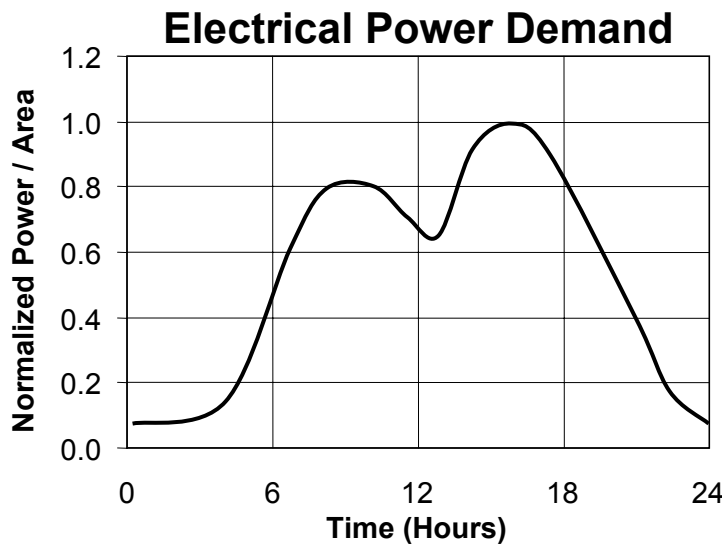
  1) directly from the Sun, and

  2) via WPT from SSP systems
- Laser light is transmitted and converted more efficiently than sun-light
  - Wavelength is selected for good atmospheric transmissivity
  - Efficient Light Emitting Diode wavelengths match common PV band-gaps
- Gravity gradient-stabilized SPSs are in peak insolation at ~6 AM and ~6 PM, with shadowing or cosine loss at mid-day and midnight
  - Heavy, complex gimbaled arrays add little extra power at these times
  - Both sides of rigid (not gimbaled) solar arrays can be light-sensitive
    - Back-side produces less power due to occlusion by wires
    - Translucent substrate (e.g., Kapton) also reduces back-side power levels
  - Even gimbaled arrays suffer a loss of power around noon and midnight
- The combination of ambient sunlight plus laser illumination combines, at the terrestrial PV array, to match the daily electricity demand pattern

Sunlight + Laser-PV WPT = ~ Power Requirement Photo-Voltaic (PV) Power Station Receives Both







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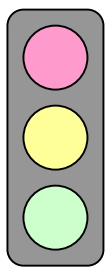
WPT Wavelength Trade for SSP

ATTRIBUTE	WPT Using Radio Waves	WPT Using Light Waves
Aperture Size	Large, so system must be large	Small; allows flexible system design
Interference	Radio Frequency Interference	None, except perhaps astronomy
Attenuation	Penetrates clouds and light rain	Stopped by clouds (need desert area)
Legal Issues	FCC, NTIA, ITU	ABM treaty, if power density high
Infrastructure	Rectenna useful for SSP only	PV array for both WPT & solar power
Dual Use	Crops?; communications?	PV arrays on rooftops; "solar"-sails?
Perception	Public fears of "cooking"	Government fears of "weapons"
Safety	Safe (must keep aircraft out of beam)	Safe (WPT light intensity < sunlight)
Efficiency (space)	High	Improving
Efficiency (ground)	High	Improving
Traceability	Heritage to communications & radar	MSC-1 and MSC-2 predecessors
Power Mgmt & Dist	Heavy, due to centralized WPT	Lightweight; WPT can be distributed



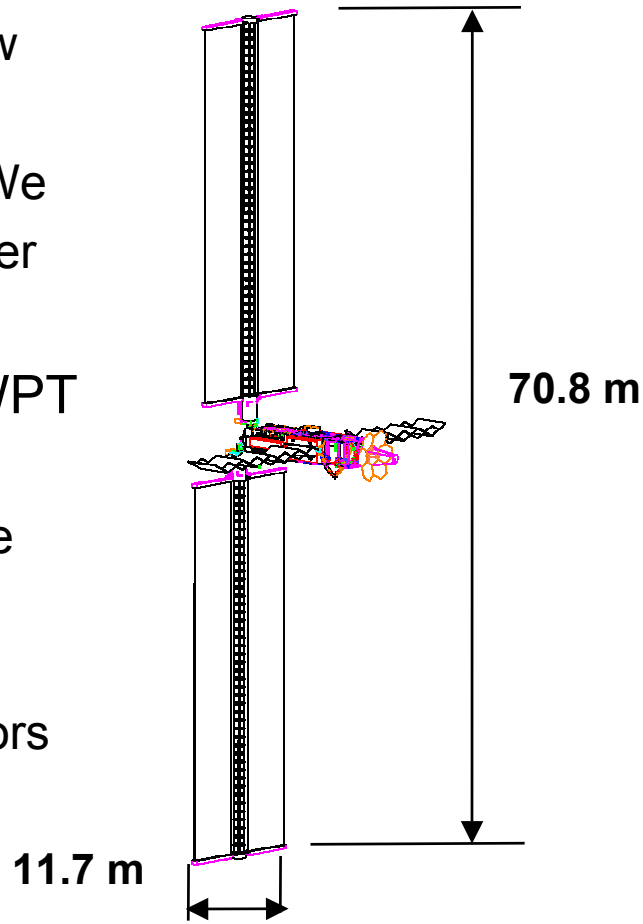
Area of Significant Concern

Intermediate Area

Area of Significant Benefit

MSC-1: Near term Demonstrations 100 kWe Power Plug Satellite

- Power System derived from existing ISS IEA (Integrated Energy Assembly)
  - IEA is successfully deployed in orbit now
  - IEA includes energy storage (batteries)
  - Current ISS array pair produces 61.5 kWe
  - Advanced PV cells can double IEA power
    - ~120 kWe with derivative array
- MSC-1 demonstrates solar-powered WPT
  - Efficient power generation
    - Light Emitting Diodes (LEDs) achieve >30% conversion efficiency
    - ~36 kW transmitted in light beam
  - Effective heat dissipation via IEA radiators
  - Accurate pointing of beam via reflector



ISS with IEA Solar Panels Fully Deployed

MSC-1A: Lunar and Mars Power (LAMP) Application